Modeling Climate and Acidification Impacts on Fisheries, Aquaculture, and Other Marine Resources

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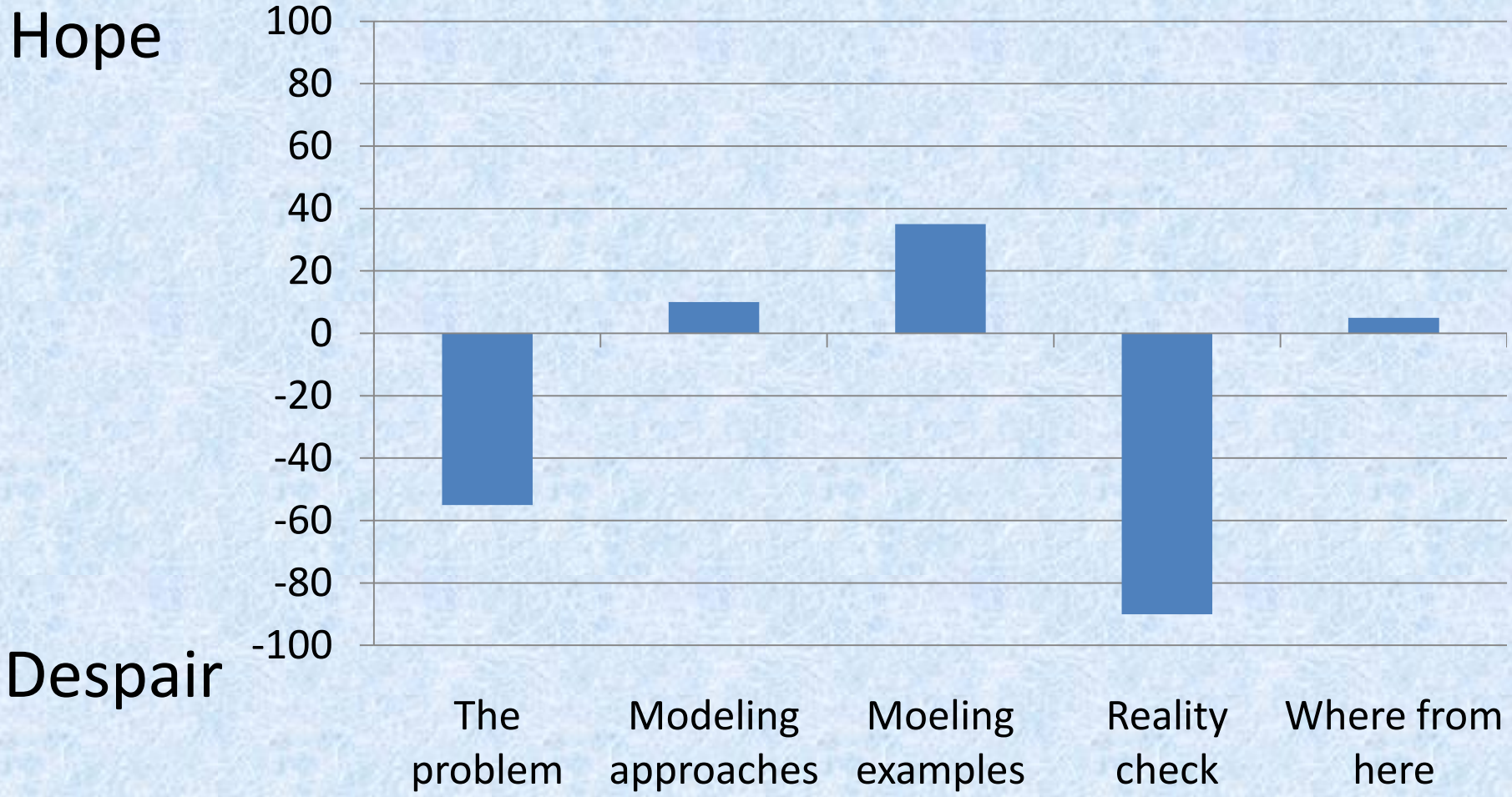
Background Photo by Jared Figurski

Talk Outline



The Problem

Living Aquatic Resource Issues

- Capture fisheries
- Aquaculture
- Endangered species
- Tourism
- Shoreline protection
- Human Health

CO_2 Effects

- Growth and Survival
- Range shifts
- Stratification/circulation
  - Nutrients
  - Oxygen
  - Dispersal
- Sea level rise
- Acidification
- Storms
- Increased UV

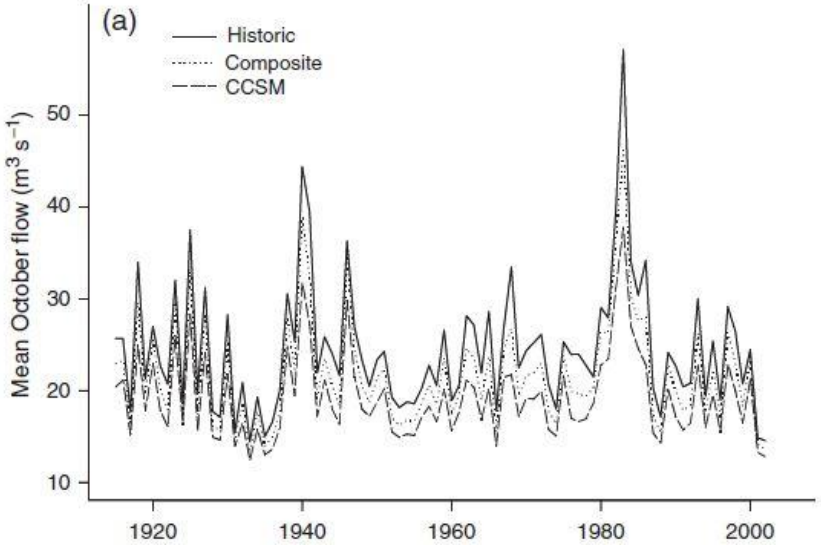
Model Flavors

- Fishery stock assessments
- Population Viability Analyses
- Food web/ecosystem models
- NPZ models
- Minimum realistic models
- Maximum unrealistic models
- Modeled range maps
- Individually-based models
- Life-cycle models
- Bioenergetics
- Expert systems

Incorporating CO2: Down-scaling IPCC- class models

- Model Scales
  - Space
    - IPCC: typically 1° x 1° (~110 km latitude) or coarser
    - IPCC: Very poor on the coasts/nearshore, fronts and eddies
    - Biological scales: Sometimes meters mater
  - Time
    - IPCC: Does not resolve decadal scale patterns
    - Biological scales: annual and seasonal variation mater
- Key Features to down-scale
  - Temperature
  - Stratification/Circulation/Salinity
  - Storms
  - Sea level
  - Carbon Chemistry

Example 1: Salmon life-cycle, Climate change and stream flow

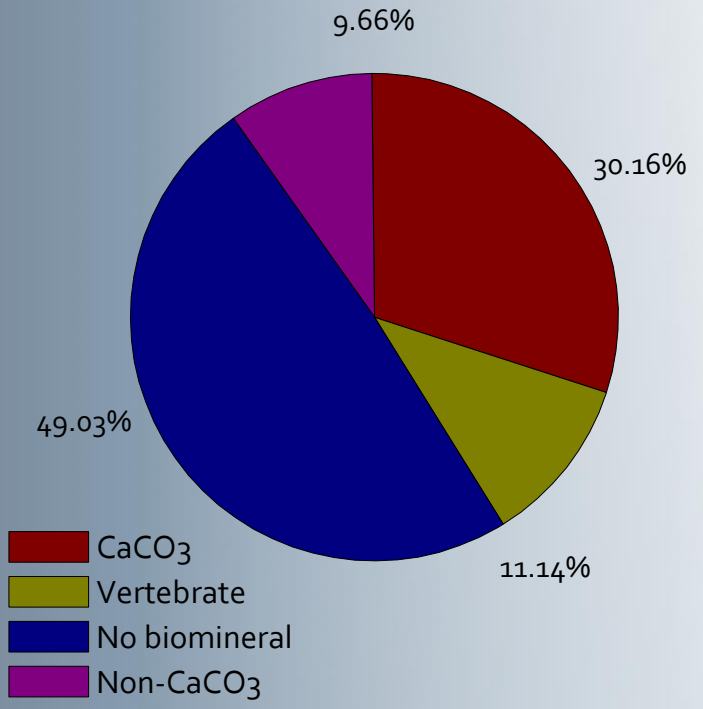


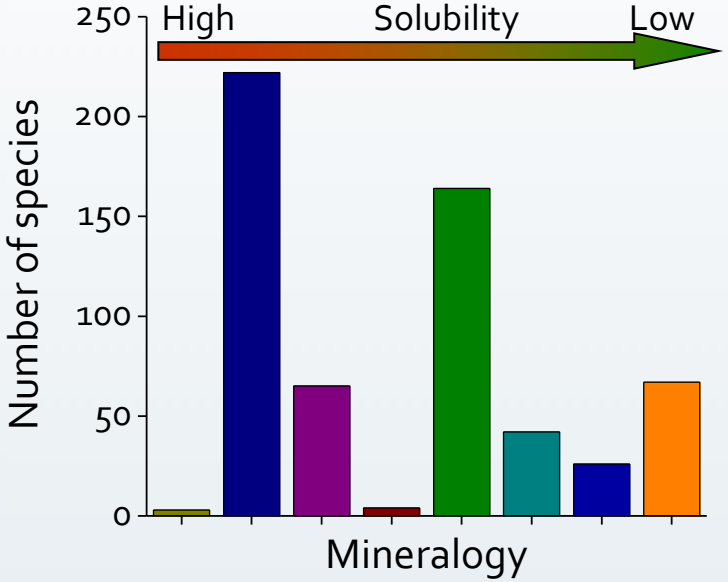
From Crozier et al. 2008

Life-cycle from McElhany et al in prep

Example 2: Acidification in Puget Sound with Ecopath/Ecosim

Calcium carbonate mineralogy

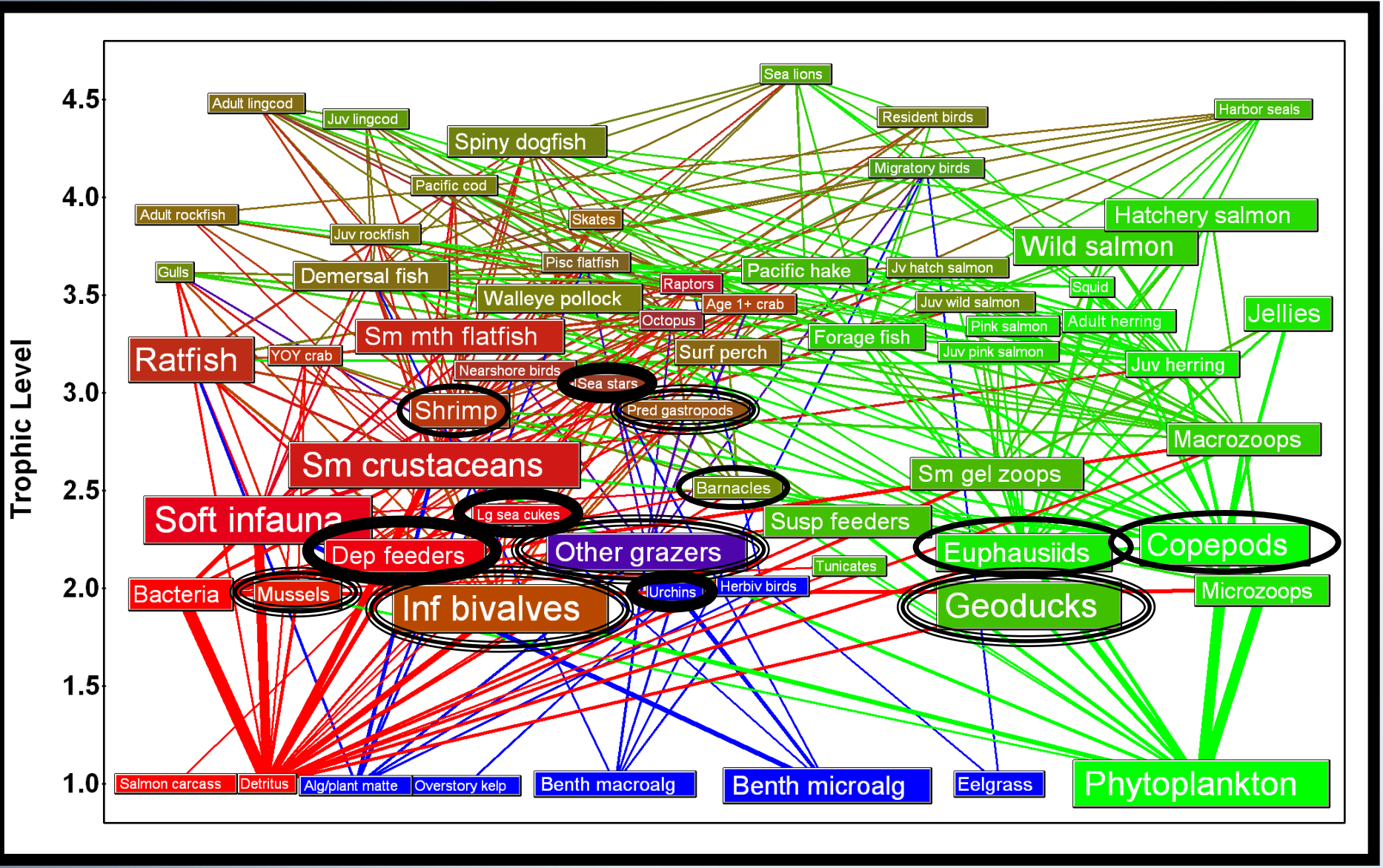




Mostly amorphous $CaCO_3$, some calcite
High Mg calcite, some amorphous $CaCO_3$
High Mg calcite
Mostly aragonite, some high Mg calcite
Aragonite
Mostly aragonite, some calcite
Mostly low Mg calcite, some aragonite
Low Mg calcite

From Busch, Harvey and McElhany in prep

Puget Sound Ecosystem



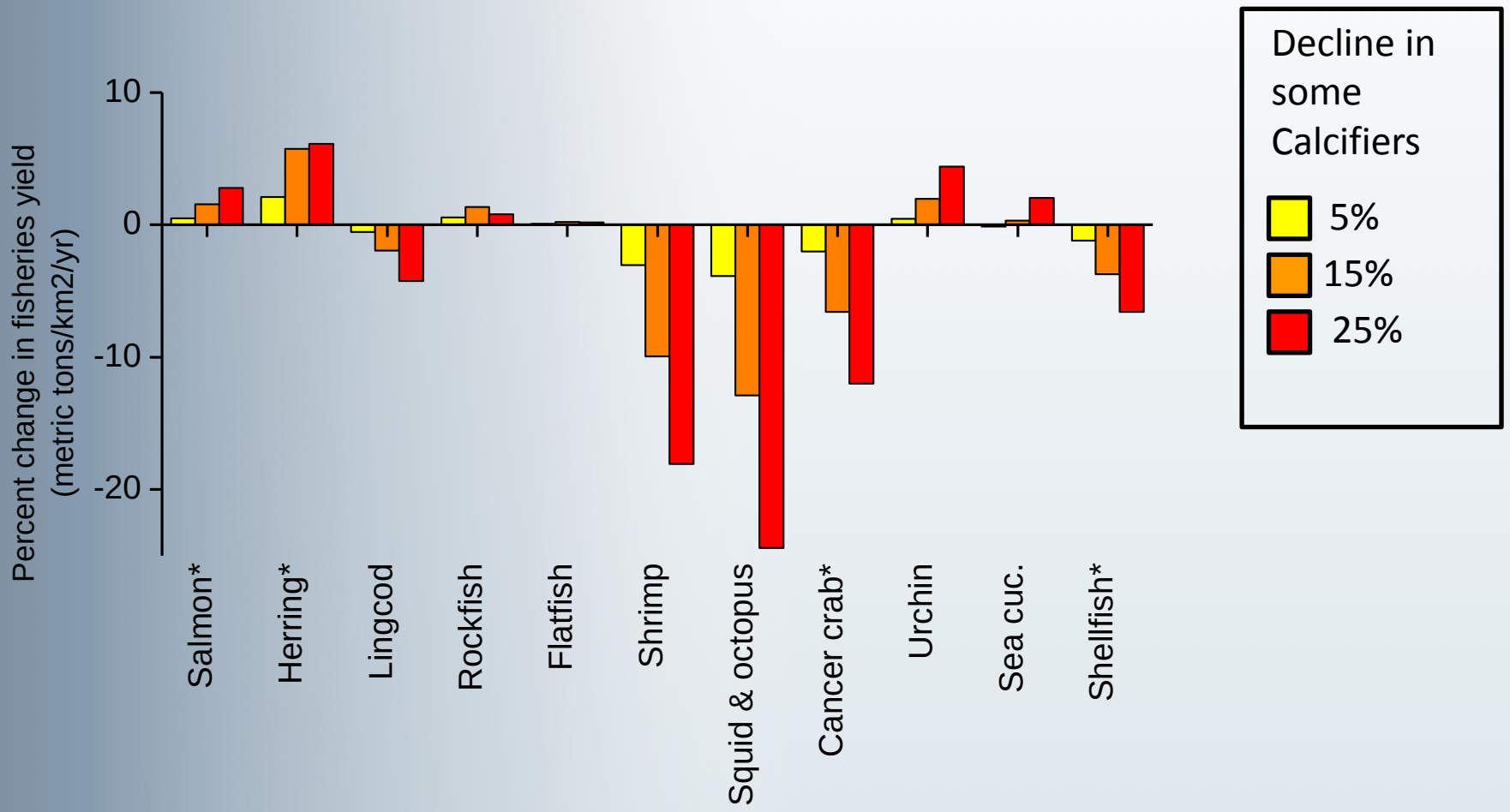
Busch, Harvey and McElhany in prep

"Because of their enormous size, the chemical composition of the open oceans, with the exception of lead, has not been greatly affected by human activities."

Kates and Parris. **2003**. Long-term trends and a sustainability transition. Proceedings of the National Academy of Science

NWFSC OA Research Lab

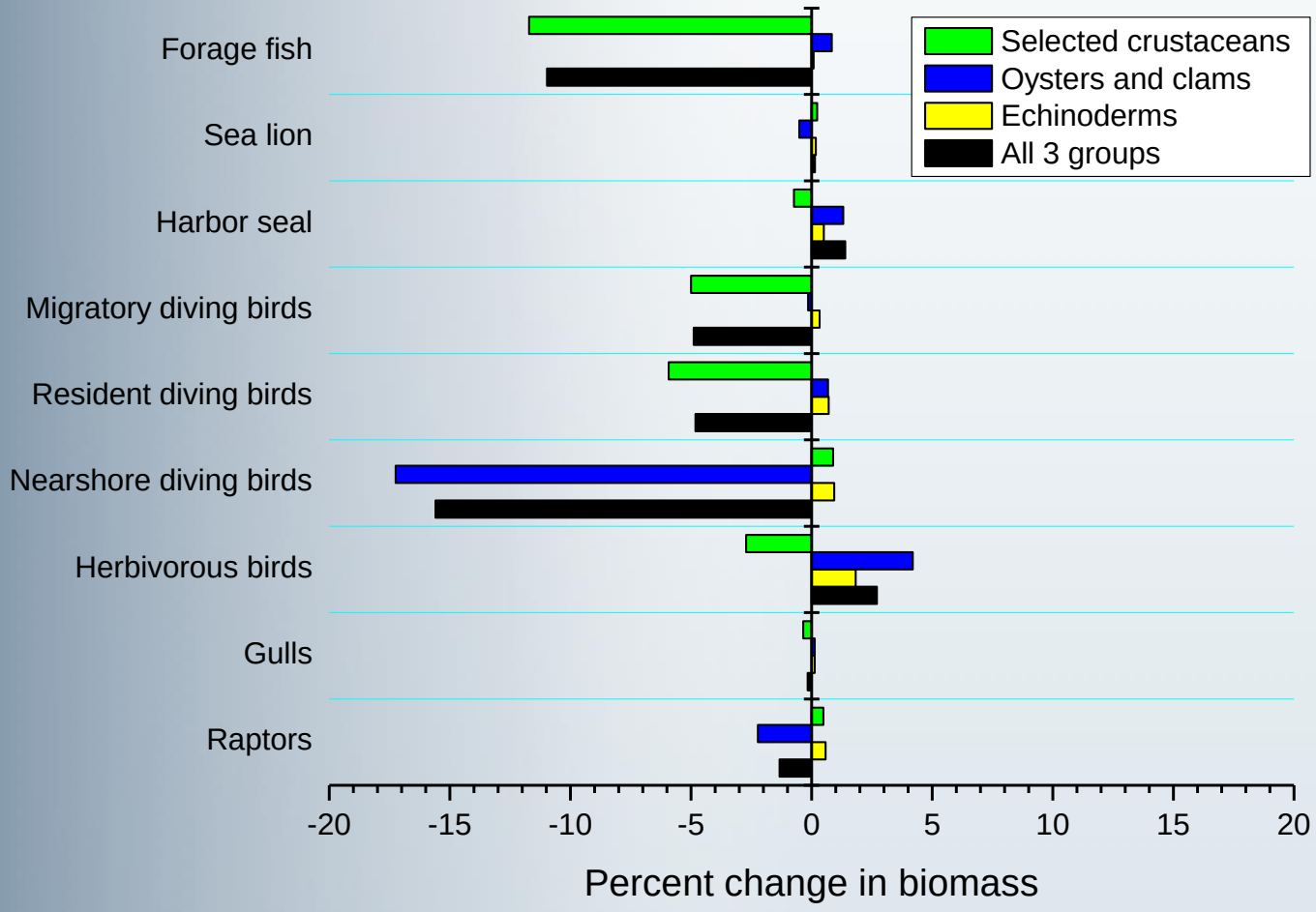
Impacts on Puget Sound Harvest?



Busch et al. in prep

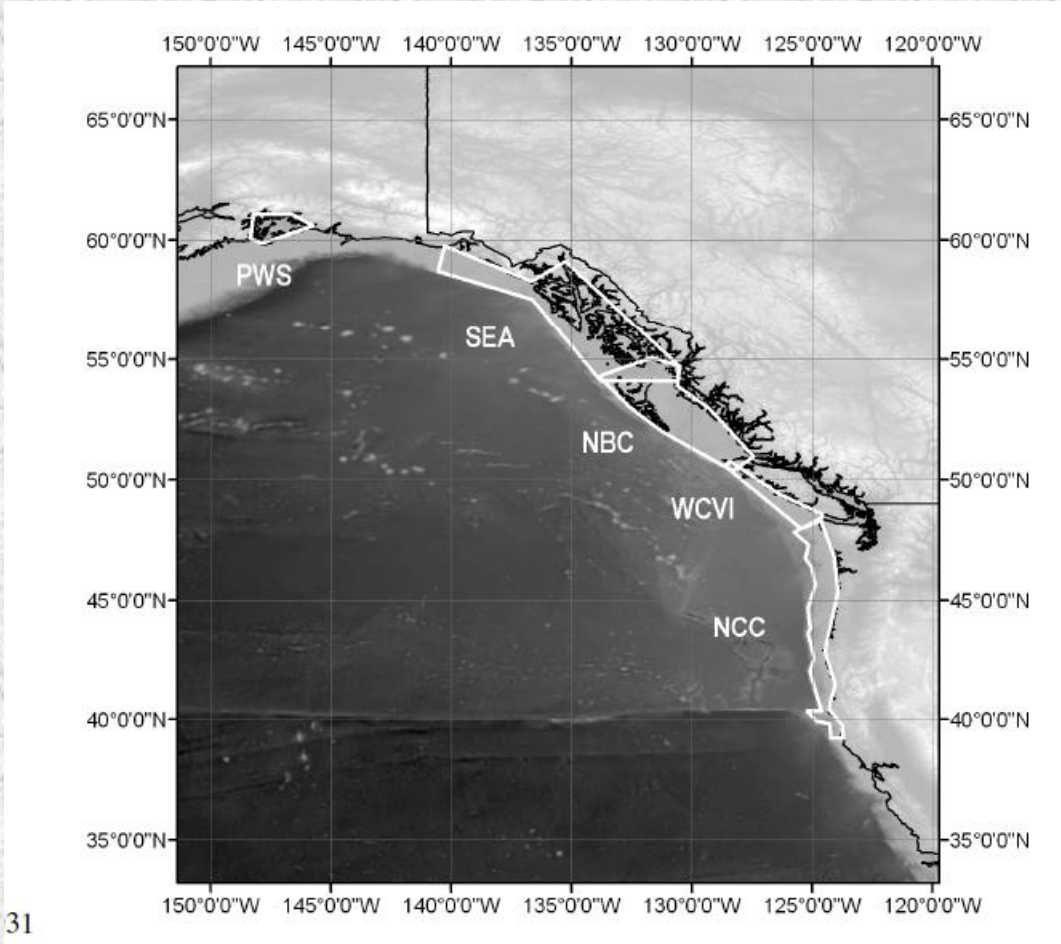
Impacts on Puget Sound Biomass?

From a 25% decline in some calcifiers



Busch et al. in prep

Example 3: California Current, Climate and OA with EwE (Ainsworth et al.)



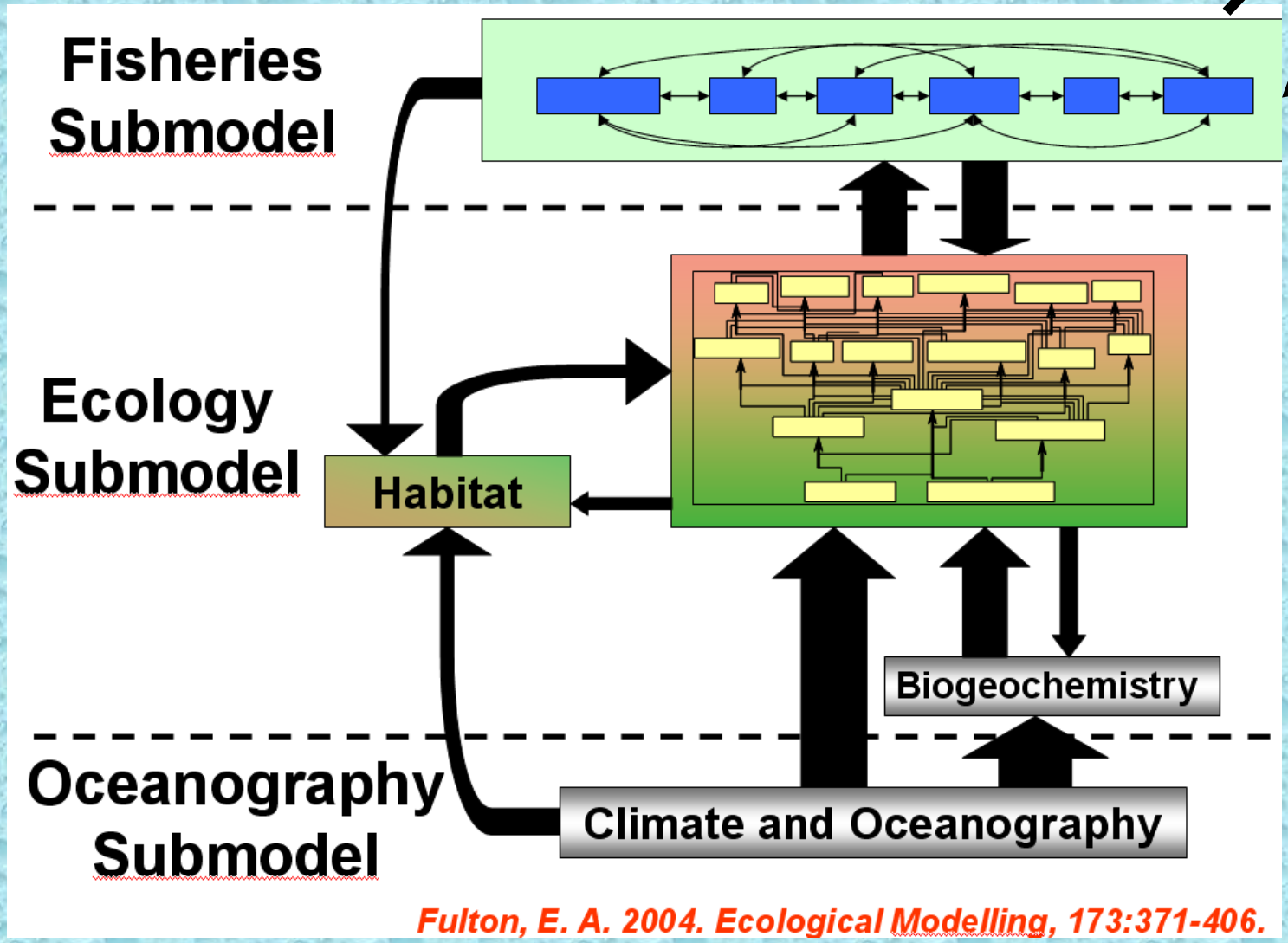
California Current Climate Effects

- Primary productivity (from GFDL ESM2.1)
- Biogeographic range shifts (from Cheung et al.)
- Zooplankton size structure (Moran 2009)
- Ocean acidification (Busch et al. review)
- De-oxygenation (Whitney 2007)

Result Summary

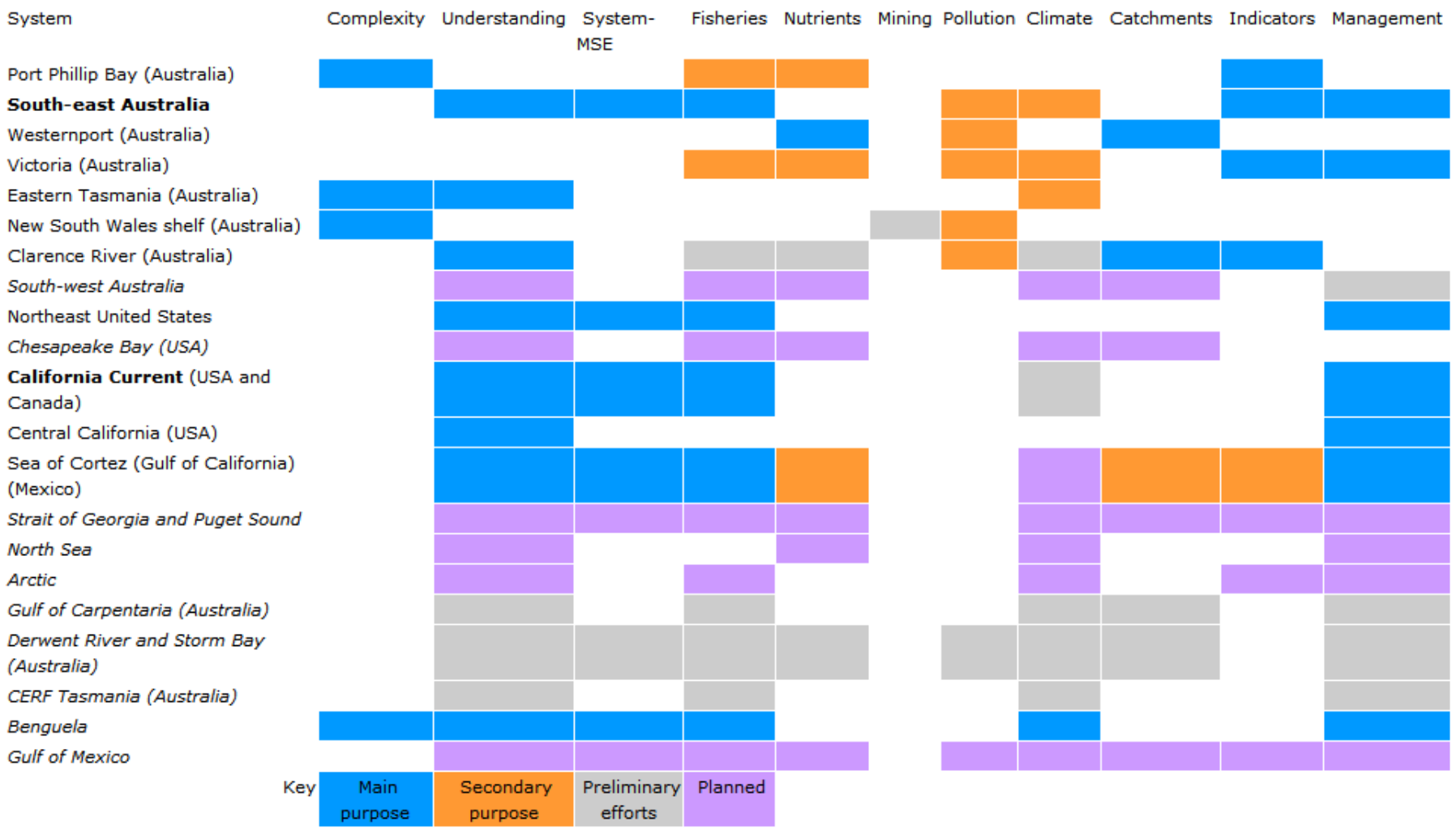
- General decline in fisheries, especially with all climate effects
- Range shifts biggest impact

Example 4: Atlantis

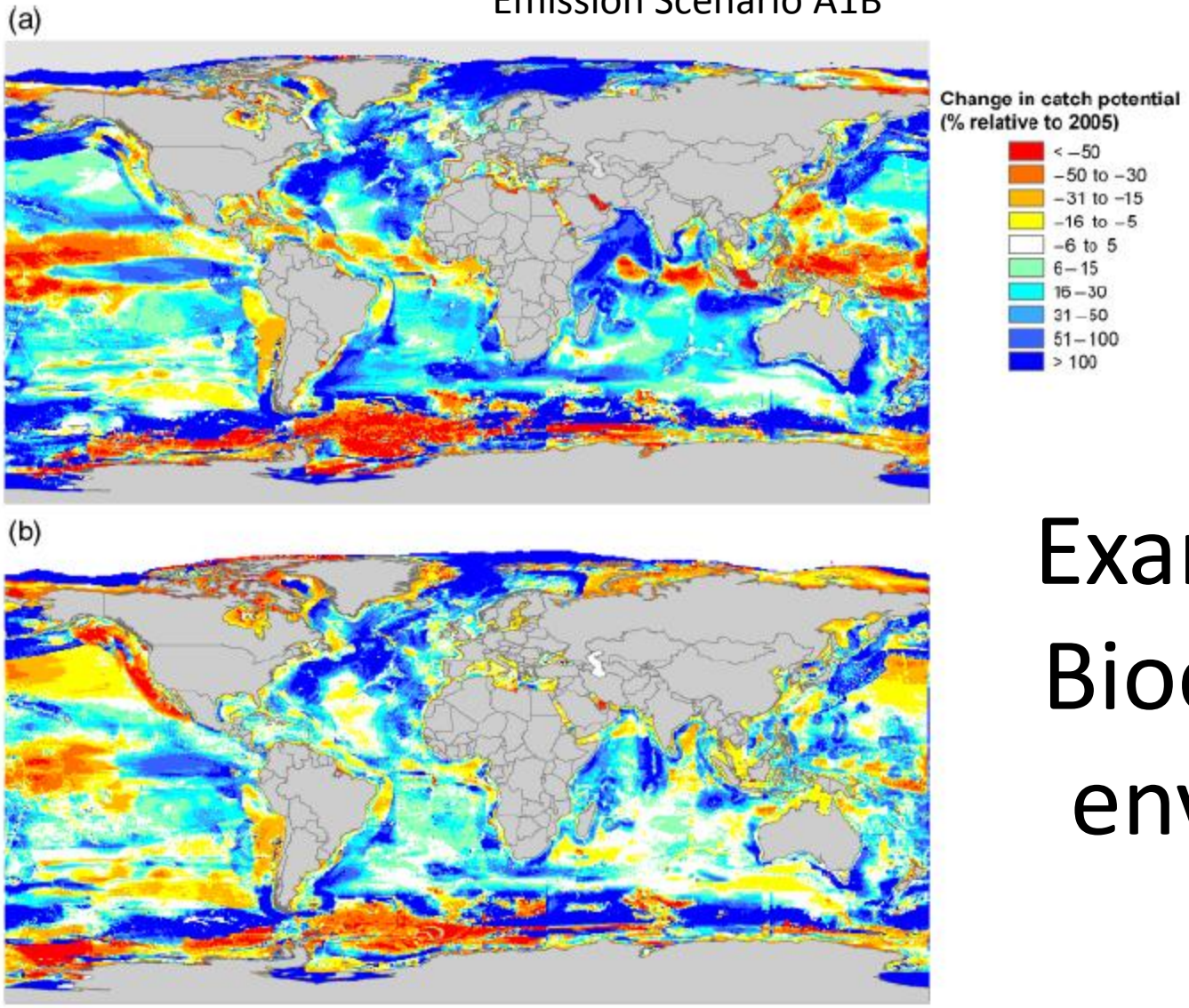


Fulton, E. A. 2004. Ecological Modelling, 173:371-406.

Atlantis Applications



Emission Scenario A1B

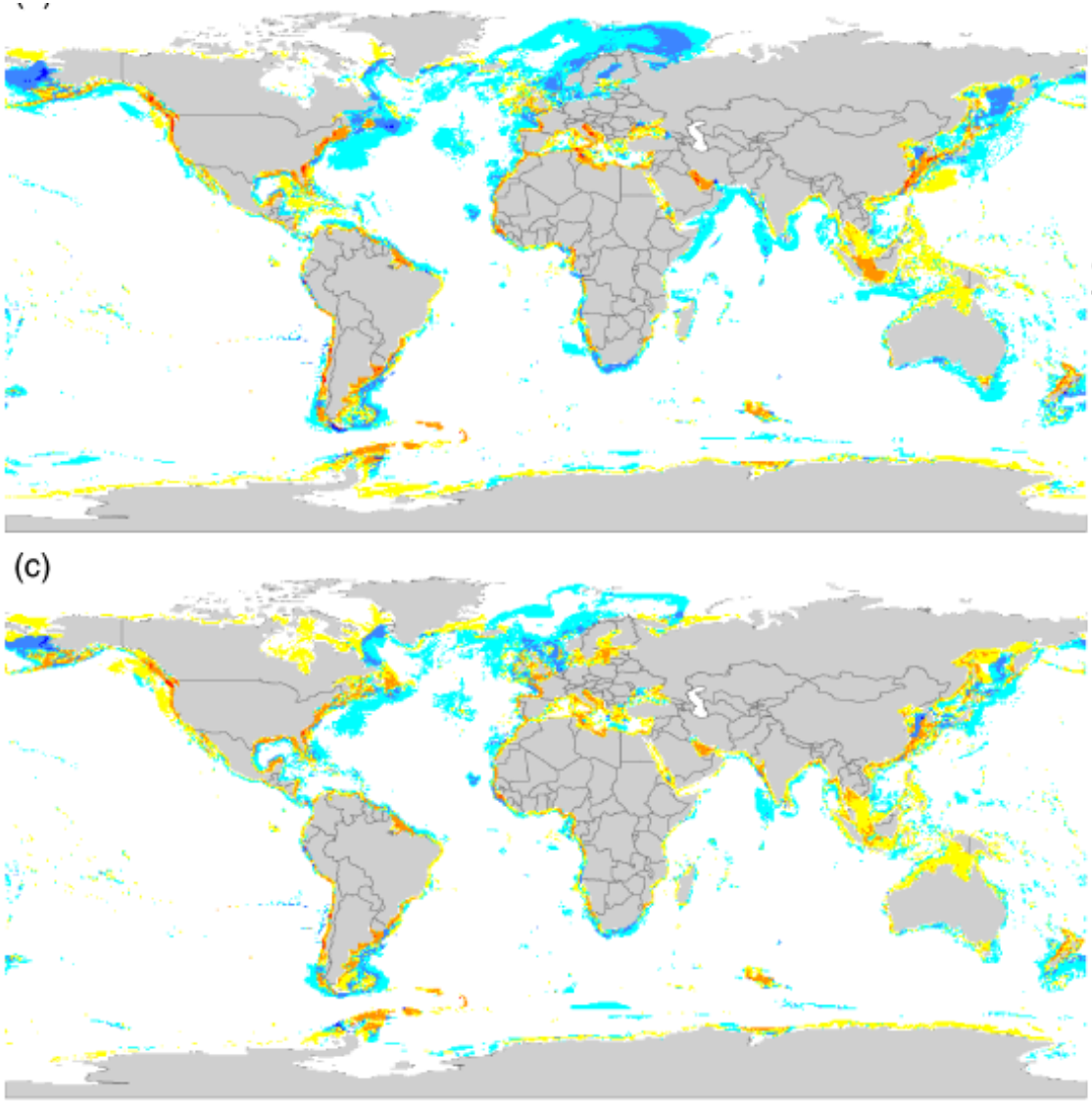


2000 Emission Scenario

Example 5: Bioclimate envelope

From Cheung et al. 2009

Projected Change in Catch

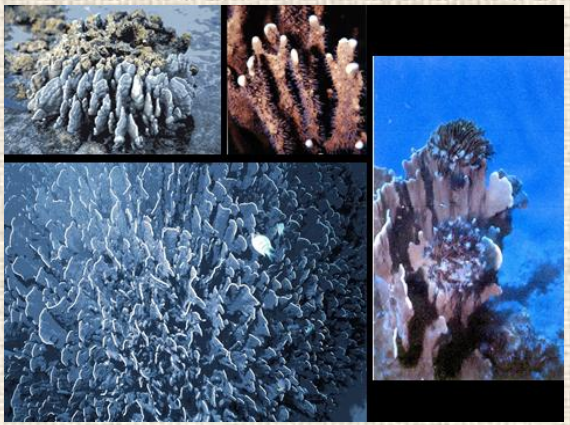


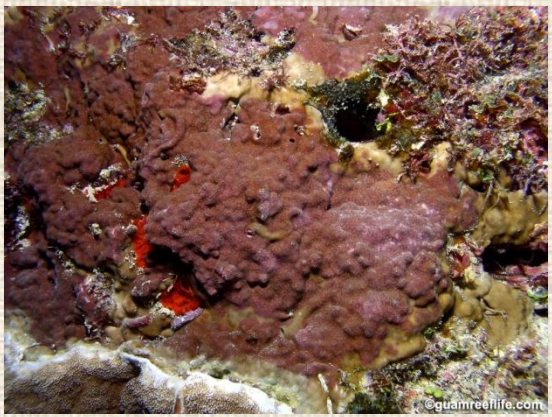
Emission Scenario A1B

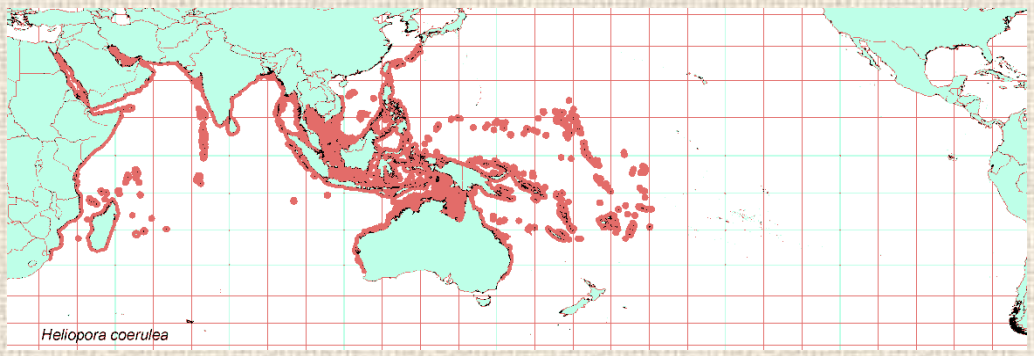
2000 Emission Scenario

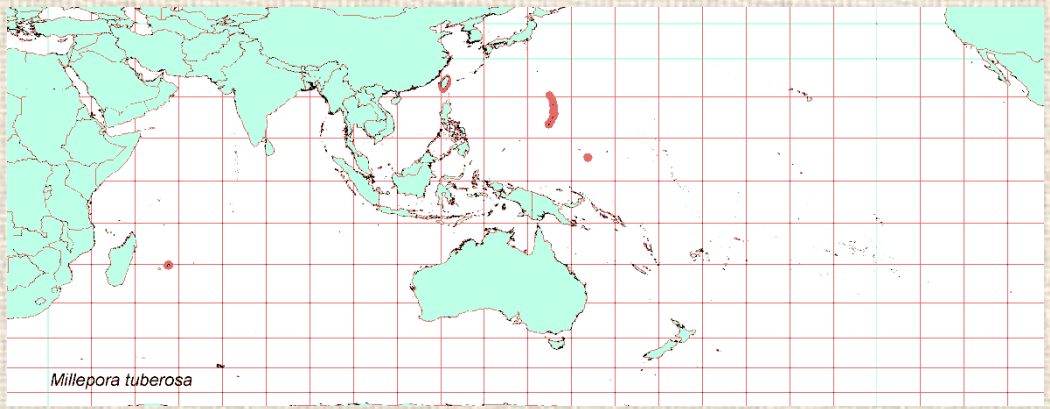
From Cheung et al. 2009

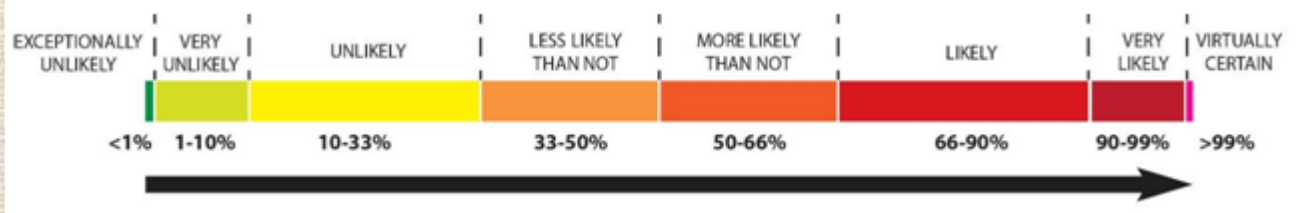
Example 6: Extinction risk for 82 species of tropical corals



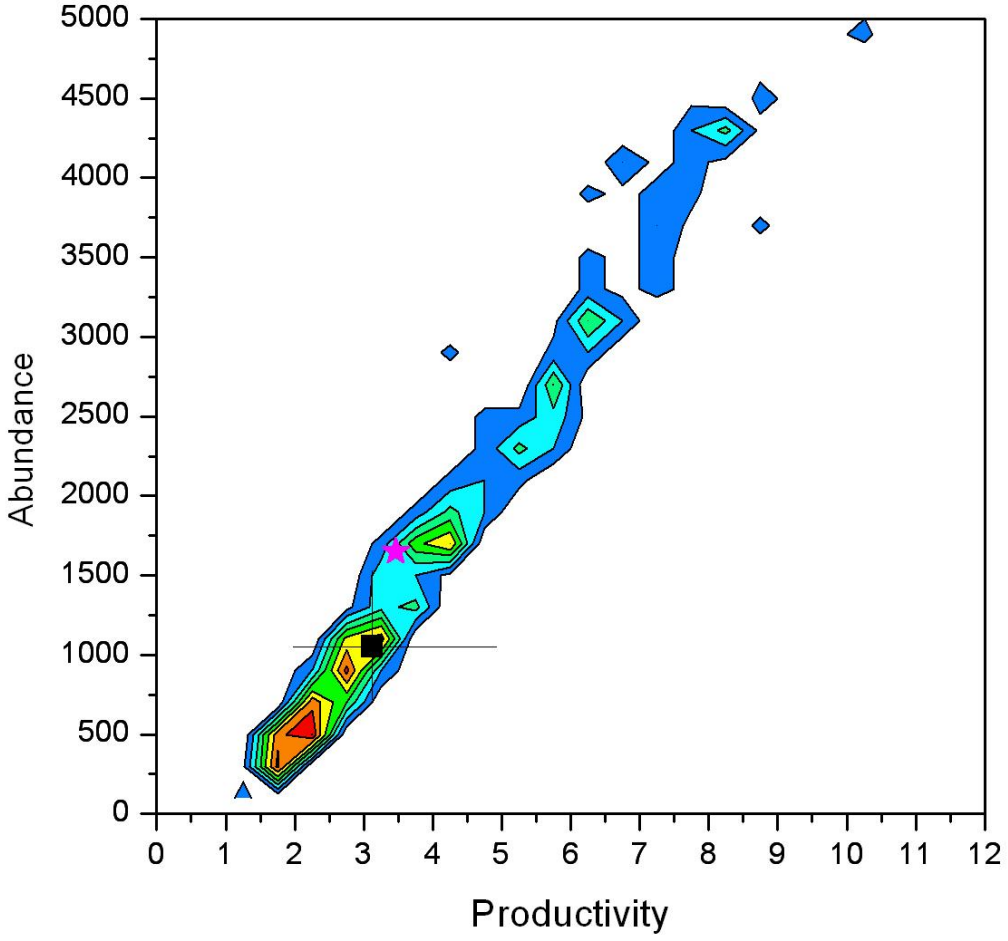








Incorporating Uncertainty



Uncertainty changes mean, not just the range

From McElhany et al. 2010

Reality Check – Some big questions

- Florida – yes or no?
- Gulf stream – same
- Increased stratification – how much, where, effect?
- Upwelling – same
- Decadal oscillations (“regime shifts”)???
- Adaptation to OA and temp?
- Ice ecosystems?
- Rainfall changes and freshwater systems – where, how much
- Where will fishing get better?

Details Matter

- Species differences
- Species interactions (predator-prey mismatch)
- Phenology
- Synergistic effects
- Short term variability
- Local circulation
- Lab studies don’t scale to ecosystems

Moving Forward: Coarse scale impact assessment

- Back Of Envelope (BOE) estimates
- Three Approaches:
  - Bioclimate envelope as key first pass estimates
  - Minimum realistic models on high value fisheries
  - Ecosystem/foodweb to look for interactions
- Resolution of big climate questions

Some References

- Cheung et al. 2009. Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Global Change Biology.
- Kevern et al. (ed). 2009. Climate change implications for fisheries and aquaculture. FAO.
- Stock et al. in press. On the use of IPCC-class models to assess the impact of climate on Living Marine Resources. Progress in Oceanography.